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Quarterly Progress Report

Division 7

Engineering

15 December 1964

Prepared under Electronic Systems Division Contract AF 19(628)-500 by

Lincoln Laboratory

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Lexington, Massachusetts

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INTRODUCTION

The Engineering Division, in the quarterly period from 1 September to 30 November 1964, was principally concerned with three major projects. These were the Haystack antenna, the optical instrumentation of the KC-135 aircraft, and the Lincoln experimental communications satellite.

The Haystack Hill experimental facility, formally dedicated on 8 October, is undergoing mechanical system testing and debugging, and final construction work within the radome and about the building is being completed.

The major portion of Phase III of the optical instrumentation of the KC-135 aircraft under the PRESS Program was completed successfully before the plane departed for Honolulu on 11 November. The last unit, the long focal length camera, will be completed and installed by mid-February.

Fabrication and environmental testing of the series of experimental communications satellites known as LES constitute the major effort of the Division at this time. This project is being carried out in cooperation with Division 6. An all-out effort is being made to achieve a successful first launch in January.

J. F. Hutzenlaub
Division Head

15 December 1964

Accepted for the Air Force
Stanley J. Wisniewski
Lt Colonel, USAF
Chief, Lincoln Laboratory Office

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TABLE OF CONTENTS

ORGANIZATION

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MECHANICAL ENGINEERING
GROUP 71

The Mechanical Engineering Group provides engineering and design support for all Laboratory programs. At present, the major efforts are for the Haystack project and the Space Communications and PRESS Programs.

I. GENERAL RESEARCH

Approximately 20 percent of the Group's design effort is in support of the General Research Program. The principal tasks are summarized as follows:

A. Closed-Cycle Refrigerators

Closed-cycle refrigerators for use with low-noise receivers continue to be evaluated. A Malaker Laboratories unit, which provides 1 watt of cooling at 30°K, and an Arthur D. Little cryodyne, which provides 0.6 watt of cooling at 4.2°K, are being given system tests under continuous operation.

B. 8.5-mm Lunar Radar

The 8.5-mm lunar radar on the roof of Building D is being improved by the installation of new speed reducers and drive motors, together with their associated controls.

C. 84-Foot-Diameter Tracker

At Millstone Hill, the 84-foot-diameter tracker system continues to be improved. Installation of WR-770 waveguide and high-power rotary joints, as well as a variable polarization unit and a new TR switching unit, should be completed by the end of 1964.

D. Structures Research

Work has continued on paraboloidal shell analysis and on the improvement and development of computer programs for the analysis of framed structures.

1. Paraboloidal Shell Analysis

Emphasis during this quarter has been on:

(a) The solution for a symmetrically loaded paraboloidal shell with an interior support.

(b) The automatic calculation of the surface phase error caused by the calculated distortions.

(c) The extension of the honeycomb sandwich shell programs.

2. Framed Structures Analysis

The FRAN (frame analysis) check step has been operating successfully and no new errors have occurred. This program modification is therefore considered complete. The plate-shell

analogy program is working in an initial form and is undergoing evaluation before writing the final program.

The previous STAIR (structural analysis interpretive routine) work on matrix "ill-conditioning" detection and inversion is essentially complete. New STAIR modifications have been initiated in the matrix setup, reduction, and addition routines to expand its capability. These modifications considerably relax certain serious restrictions.

An attempt has been initiated to improve the running time of the FRAN program. The use of the disk file in place of the present tape units for auxiliary core storage, addition of buffering of input and output, multiple channel operation, and certain machine language subroutines will save considerable time.

The present computer program being used for dynamic analysis has an upper limit of 130 degrees of freedom. This means a capability of only 25 to 50 joints, depending upon the type of structure being analyzed. The program is now being expanded to 1300 degrees of freedom so that structures such as the Haystack antenna can be dynamically analyzed for natural frequencies and mode shapes. This effort is well under way and should be essentially completed during the next quarter.

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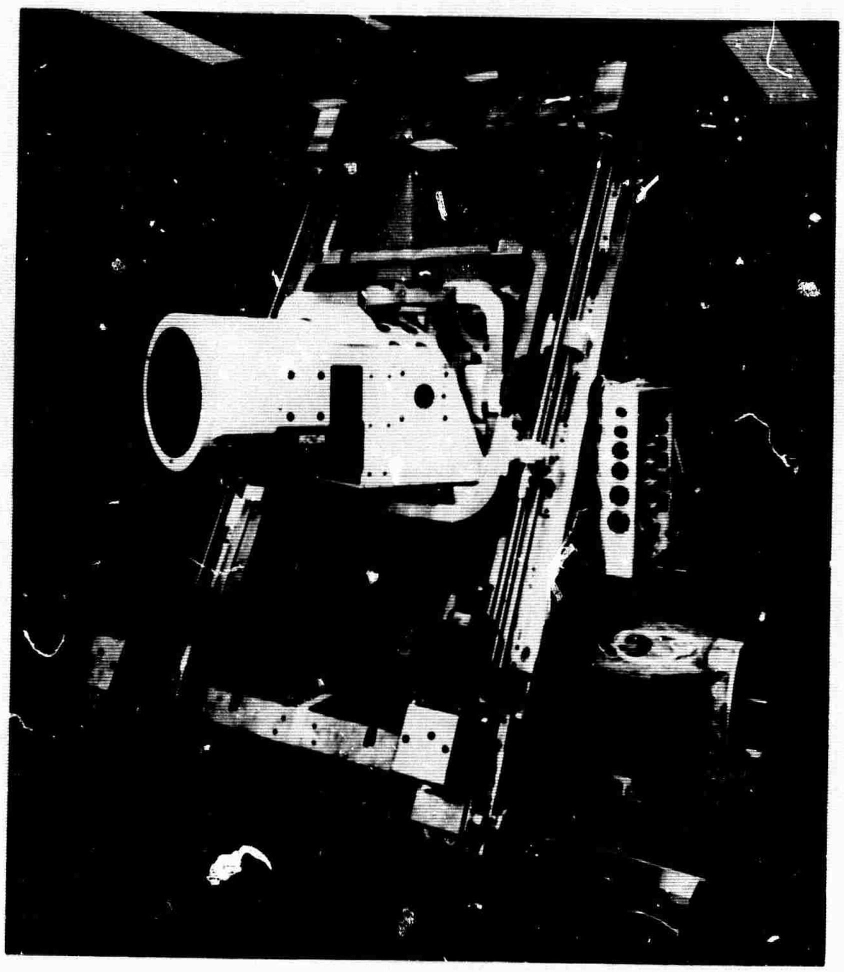

Fig. 71-1. Assembly of the long focal length camera to be installed in the KC-135 aircraft.

II. PRESS PROGRAM

A. KC-135 Airborne Instrumentation

Following a careful assembly and control system checkout of the airborne optical instrumentation system at the mockup in Lincoln Laboratory, the equipment was installed in the KC-135 aircraft. The entire installation, including a "power on" checkout, was accomplished in only twenty-one days. After the necessary ground tests and two successful star tracking flights, the plane departed for Honolulu on 11 November.

Assembly of the forward instrument mount (long focal length camera) is proceeding on schedule. See Fig. 71-1. Elevation and deflection servo systems tests as well as horizontal translation system tests can begin before 1 January 1965. Final tailoring of the vertical translation counterbalances is the critical item. Assembly into the aircraft at Hawaii should be completed by mid-February.

B. Calibration and Ground Support Equipment

The calibration collimator for METES has been assembled and wired. Installation of the optical elements and packaging of the balance of the electronics should permit shipment of the entire collimator to Hickam Field prior to the end of December.

C. 48-Inch Spectrometric Telescope

1. New Tracker

The new tracker for the 48-inch spectrometric telescope is nearing completion by the manufacturer. It will then be extensively tested here before its integration with the system at the PRESS field site.

2. 48-Inch Collimator

A collimator for use with the 48-inch spectrometric telescope is being designed. It consists of the same optical elements as the telescope with a 48-inch primary and a 16-inch secondary mirror. The 48-inch primary mirror will include a 48-inch flat on its reverse side which will be employed for certain experiments. The equipment will be installed at the Pacific site next year.

III. SPACE COMMUNICATIONS

A. Lincoln Experimental Satellite

Nine complete satellite assemblies or "payloads" are being prepared. Those which are scheduled for qualification tests or for the actual Titan launches are:

Payload A	Structural design verification tests (engineering model)
Payload B	Spin, drop, and satellite ejection tests (skeleton satellite)
Payload 1	Structural qualification tests and mass measurement tests (dummy electronics)
Payload 2	Thermal-vacuum and acoustic tests (retrofit to flight configuration for use as flight backup for LES-1, LES-2, and LES-3)

Payload 3	LES-1 flight payload, launch vehicle Titan IIIA FTV-3 (1965)
Payload 4	LES-2 flight payload, launch vehicle Titan IIIA FTV-6 (1965)
Payload 5	LES-3 flight payload, launch vehicle Titan IIIA FTV-5 (1965)
Unassigned	LES-4 flight payload, Titan IIIC launch (1965)
Unassigned	LES-5 flight payload, Titan IIIC launch (1966)

The Titan launches will be from the Eastern Test Range, Cape Kennedy, Florida. Detailed operation sheets are being prepared for each task performed away from Lincoln Laboratory, and full-scale assembly rehearsals are being conducted by those who will perform the same operations at Cape Kennedy.

1. Test Program

Detailed test specifications have been prepared which spell out the entire test program for systems as well as subsystems.

Payloads A and 1 have been subjected to a complete series of shock and vibration tests, including a resonant frequency survey, random vibration at 125 percent of the design load, and a shock load whose response spectrum was determined to equal or exceed the requirements. Payload 1, which was complete structurally and which contained all wiring and antennas as well as partial electronics, sustained some structural damage during the vibration tests when the X-band transmitter and receiver boxes tore loose from their fastenings. These have been redesigned. Subsequent qualification tests have revealed no further damage.

Each electronic package to be flown is subjected to three random vibration acceptance tests. At least one specimen of each package type is subjected to both sinusoidal and random vibration tests at specified over-loads.

2. Booster and Spin Housing Assembly

The spin and ejection assemblies for payloads 2 and 3 have been completed and have undergone calibration testing. Each test was photographed with high-speed film to record the smooth separation of the assemblies. In addition, the rocket motor housing assemblies and the satellite ejection housing assemblies for both payloads have been completed.

3. Electronic Packaging

Electronic packaging designed at Lincoln Laboratory for the LES transponder falls into two main categories, depending on the type of circuitry to be packaged. Circuitry operating from DC to about 1.5 Gcps uses lumped components and is packaged in functional units. A package consists of a series of cavities machined in an aluminum block with integral shielding between the various stages of the circuit. Whenever possible, the package is so arranged that all DC portions of a circuit are on one side of a mounting plate, and all RF portions on the other side. Tuning adjustments are made from the DC side, which is accessible when the unit is installed in the satellite. This type of package is provided in the satellite for frequency-multiplying and power-amplifying circuitry. It uses both transistors and varactors in combination with lumped-constant tuned circuitry.

Higher-frequency circuits, operating between 0.854 and 8.29 Gcps, are packaged in stripline, which consists of etched RF transmission lines sandwiched between two dielectric sheets. For mechanical rigidity, the striplines are mounted in machined boxes of 0.062-inch-thick aluminum and held together with screws which also provide insulation between the stripline elements on a single board.

The complete transponder is assembled as two packages of approximately equal size and weight, mounted opposite one another on the satellite frame. The chassis are machined aluminum boxes, approximately 9 × 9 × 2 inches. These boxes provide support mountings on their inner and outer surfaces for the individual packages previously mentioned.

Interconnections between individual packages and the two large chassis comprising the transponder are by miniature coaxial cable, either flexible or rigid, depending on the frequency of the particular signal.

The first transmitter and receiver have been assembled and are undergoing final checkout and qualification testing.

4. Telemetry Antennas

Twenty-two redesigned telemetry antennas have been fabricated. The new configuration has successfully passed electrical and structural testing. Telemetry antennas have been installed on three satellites.

The telemetry antenna coaxial cables have been fabricated and installed in three satellites. Minor changes in routing, caused by interference with other equipment in the satellite, were incorporated in the second and third set. Six sets of telemetry antenna cable support brackets have been fabricated and four sets have been installed in satellites.

B. Lincoln Experimental Terminal

1. LET Vehicles

The three vehicles which make up the terminal are all in final assembly at this time.

a. Antenna Vehicle

This vehicle has three major parts. The antenna pedestal is in the final stage of machining in Maine; its power drive gearing and elevation and azimuth gearing are being delivered to the Laboratory. The equipment shelter, which attaches to the pedestal, will be the last item to be completed. The running gear, for use when the vehicle is towed over the highway, consists of two detachable wheel and axle assemblies. These assemblies have been received. It is expected that the antenna vehicle will be delivered to the Laboratory in mid-January, after which it will be equipped.

b. Electronics Van Trailer

This vehicle contains the power-generating equipment and will provide the main working area and antenna reflector stowage. Equipment racks and antenna stowage facilities are being installed in the trailer at the Laboratory.

c. Prime Mover

This tractor-type truck, which will provide mobility for the two other vehicles of the terminal, is an all-wheel-drive cab-over-engine vehicle with a front-mounted 10,000-pound-capacity winch. Lincoln Laboratory personnel are now modifying this vehicle to provide stowage for some of the miscellaneous items of the system.

2. Parametric Amplifiers

Four parametric amplifiers have been completed and are undergoing room-temperature evaluation tests. Dewars for the closed-cycle refrigerator have been received and are awaiting delivery of the Arthur D. Little Model 340 system. A backup system of bulk liquid nitrogen batch-type filling has also been designed. This system will allow for the operation of the amplifiers at nitrogen temperatures.

3. RF Components

Testing of the RF component prototypes has been completed, and final units are being manufactured for installation in the antenna vehicle. The waveguide system between the tracking feed, the parametric amplifiers, and the klystron has been mocked-up and all components are either on hand or about to be delivered. The cooling system for the klystron has been installed in the mockup of the equipment shelter and will be tested before final installation.

C. West Ford Antenna Subreflector

A new subreflector to replace the type now at Westford and Camp Parks has been designed and is now being manufactured. This reflector will include UHF antennas to permit fine tracking of the LES UHF telemetry signal. The antennas will be of the cross-slot-cavity-backed type which will be RF choked to prevent interaction with the X-band frequency. All the RF components connected with these antennas will be located behind the subreflector.

Installation at the Westford site will take place early in January.

IV. RADAR DISCRIMINATION TECHNOLOGY

A. AMRAD – White Sands Missile Range

During this quarter, M. W. Brawn assumed the duties of site mechanical engineer at White Sands to replace B. A. Dudley who returned to Lexington. Mechanical activities at the site consisted of:

(1) Replacing the klystron tube tank with one designed for the new Eimac tube and new modulator.

(2) Installing uncooled parametric amplifiers for evaluation.

(3) Replacing one equilibrator because of leakage.

(4) Replacing one azimuth clutch because of a burned out coil.

(5) Disassembling and cleaning three elevation-buffer stops and installing new seals because of malfunctioning.

(6) Cleaning and painting the azimuth structure and tower (outside contract).

B. AMRAD – Lexington

The design of a new elevation cable wrap retrofit, including Haystack-type cables, has been completed which will alleviate a problem of broken leads in a short radius flexing area. The drum weldments are being made at White Sands and the smaller parts are being manufactured locally.

Cryogenic cooled parametric amplifiers have been designed to replace the electron-beam parametric amplifiers. These are now being fabricated. In conjunction with this, a liquid nitrogen refrigerating system is being readied by Air Products and Chemicals, Inc., for installation at White Sands.

A low-loss microwave feed system for AMRAD has been designed, the 4-horn feed has been rotated 45°, and a high-power circulator has been added to the receiving room plumbing. These changes are expected to improve the radar performance considerably. This work is being carried out together with the Raytheon Company which will do structural studies and installation drawings.

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CONSTRUCTION ENGINEERING
GROUP 75

Group 75 provides the Laboratory with in-house engineering services in the civil, structural, electrical, heating, ventilating, and air conditioning fields. During this quarter, the Group applied most of its effort to the supervision and coordination of the many construction projects that were in progress.

I. DESIGN AND CONSTRUCTION

A. Lexington

1. TRADEX Data Processing Center

Modifications to Building J to house the TRADEX data processing center have begun. This construction should be completed by the end of January.

2. Re-entry Simulating Range

The Re-entry Simulating Range has been enlarged by 4000 square feet to accommodate an additional light-gas gun, a new test laboratory, and an enlarged light-gas gun. The three new areas were built and finished prior to cutting into the existing facility. The new concrete tunnels are designed (as are the existing ones) to withstand projectile impact in case of a gun explosion. All construction has now been completed, including new lights, an enlarged boiler, and improved facilities.

B. Westford

1. Millstone Hill Storage Building

Construction of laboratory space in the Millstone Hill storage building is now complete. This area consists of 1200 square feet – laboratory space 900 square feet, boiler room and sanitary facilities 300 square feet. The roof deck of this area was designed to carry 100 pounds per square foot, thus utilizing the area for light storage. Lighting was added for 6000 square feet of floor space, and a 3000-pound hoist and monorail was installed.

2. Communications Site

At the Communications Site, a permanent 5000-gallon oil storage and oil supply system was installed to feed the 125-hp boiler that provides heat to the inflated radome. A small metal lean-to building was constructed to provide shop space at the site.

3. Zenith Antenna

The zenith antenna structure has been improved for maintenance and calibration. The entire surface (one acre) has now been painted, and the gravel insulation cones which prevent foundation frost damage have been sealed with oil to prevent erosion.

The supporting structure is now being repaired to correct broken splices, loose guys, braces, spring calibration, post grades, and surface sags.

C. White Sands Missile Range

The construction contract for the additions and alterations to the AMRAD facility has been awarded by the Albuquerque District Corps of Engineers, and construction is under way. An expedited schedule is in effect, and the new completion date is set for mid-May instead of July as originally planned.

Bids for the AMRAD clutter shield were received in late October by the Albuquerque District Corps of Engineers. The contract was awarded and the notice to proceed was issued on 12 November 1964. Construction work is in progress and the project is scheduled for completion by mid-July 1965.

CONTROL SYSTEMS
GROUP 76

Group 76 is responsible for the design and development of control systems for various Laboratory programs. The equipment consists primarily of automatic controls involving servomechanisms and computers.

I. GENERAL RESEARCH

A. Millstone Hill 84-Foot Antenna

Work has begun on incorporating antibacklash capability in the antenna servodrive system of the Millstone Hill 84-foot antenna. All major components have been received.

B. 8-mm Lunar Mount

New drive system components for the 8-mm lunar mount have been received. Control circuits have been designed and are being built to provide increased power for the elevation and azimuth drives.

II. SPACE COMMUNICATIONS

A. West Ford 60-Foot Antenna

Angle autotrack control capability has been installed and tested using simulated radar error, satellite motion, and receiver noise to drive the antenna mount. Servo stabilization and compensation circuits were designed to meet the requirements of LES. Autotrack design work was supplemented by an analog computer study to show control system behavior during acquisition procedure and loss of target for the servo compensating circuits used. A report is in process which describes this work.

B. Lincoln Experimental Terminal

Effort continued on construction of the drive system electronics, installation of power distribution wiring, and final design and construction of the interface system joining the Univac 1218 digital computer with the analog control system. Provision has been made for manual control independent of the computer.

III. PRESS

A. KC-135 Optical Instrumentation

The primary effort has been the installation, checkout, and adjustment of the optics control system aboard the aircraft. In-flight tests, including checks on equipment reliability, have been performed.

B. Ground System

The ROTI was examined from the standpoint of tracking smoothness at Kwajalein. The digital data instrument servo smoothness was improved by a factor of four. Both the instrument servo and the mount servo were changed from a Type I to a Type II servo system. Evaluation of these changes must await film results from actual missions.

IV. HAYSTACK HILL EXPERIMENTAL FACILITY

A. Lincoln Laboratory Activity

1. Radar Communications Box

The interconnecting waveguide runs between the receivers, parametric amplifiers, transmitter, and arithmetic network were installed in the radar communications box. The high-voltage storage receptacle was designed, fabricated, and installed at the test dock area, but its location on the antenna itself is still being studied.

2. Test Dock No. 1

Construction of the indoor Test Dock No. 1 has been completed, including the cable interconnections between the patch panel in the control room and the test dock. The center-of-gravity detector is now operational in the test dock pit.

The radar communications box has been installed in the test dock and is undergoing final outfitting and testing. Preliminary weight and center-of-gravity measurements have been made, and indications are that this box will be well within the maximum 7000-pound weight limitation and required center-of-gravity location.

3. Construction

Construction work at the site involved many projects. The radome heating system is being installed, while temporary oil heaters are in use as an interim measure. Field tests have been conducted to determine if pressurization of the radome could reduce the "oil canning" of panels as well as the considerable amount of water leakage through the radome hubs. It was found that a pressure of $\frac{1}{8}$ inch water gauge stopped oil canning, but did not stop the water entry. Thirty-two fractures were repaired on the exterior of the radome, and all cap strip bolts above the equator were tightened.

Additional construction engineering effort included preliminary studies for environmental control of the radome, design of an oil and water-free compressed air system, design of a 4000-pound hoist system for the radome truck entrance, and installation of additional generating equipment in the switch gear room.

B. North American Aviation Activity (Antenna System)

Detailed monitoring of all phases of the Air Force and Lincoln Laboratory sponsored contracts is continuing. Activity on site and in the plant is in its final phases.

1. Antenna System Test

a. RF Operation

The radiometer box was installed, and drift scans were performed with the aid of the synchro control system. A secondary servo antenna angle repeater permitted drift scans to be performed on the moon, two stellar radio sources, and two planetary sources. Secondary reflector remote focusing operations were conducted.

b. Antenna Angle Digital Data System

This subsystem has now been placed in operation. The Lincoln Laboratory interface equipment has successfully transmitted angle data into and received angle data from the antenna angle encoding system.

c. Angle Data Calibration

Calibration tests to show pointing accuracy of the antenna system have been conducted, and the data are being reduced. The azimuth axis was checked every 16° in both directions for one revolution, and the elevation axis was checked every 8° in both directions

d. Servo Control System

Considerable difficulty has been encountered in trying to achieve the specified static and dynamic performance. Testing at star tracking rates shows a need for improvement in smoothness. Precision performance at rates up to 1 deg/sec shows that the required dynamic performance has not yet been attained.